AN X-RAY DIFFRACTION STUDY OF THE
PALEOCENE-EOCENE FLAGSTAFF FORMATION IN THE
MANTI CANYON AREA OF THE WASATCH PLATEAU,
CENTRAL UTAH

A Thesis
Presented in Partial Fulfillment of the Requirements
for the Degree Bachelor of Science

by

Daniel E. Byers
The Ohio State University

1982

Approved by

R. Vettenhorst

Advisor, Dept. of Geology

ACKNOWLEDGMENTS

I would like to acknowledge Dr. R. T. Tettenhorst, my advisor, and extend my appreciation for his never ending help and interest in producing this thesis. John Zawiskie suggested this thesis and supported it with stratigraphic information, for this I am grateful. Maureen Lorenz provided her assistance with the Scanning Electron Microscope. Finally, I am forever indebted to my parents for their endless support.

TABLE OF CONTENTS

ILLUSTRATIONS

INTRODUCTION

The objective of this study was to determine by means of X-ray diffractometry, the dolomite to calcite ratios of various beds within the Flagstaff limestone. Ultimately, it is hoped this data will lead to the reconstruction of the paleoenvironment of fossil birds.

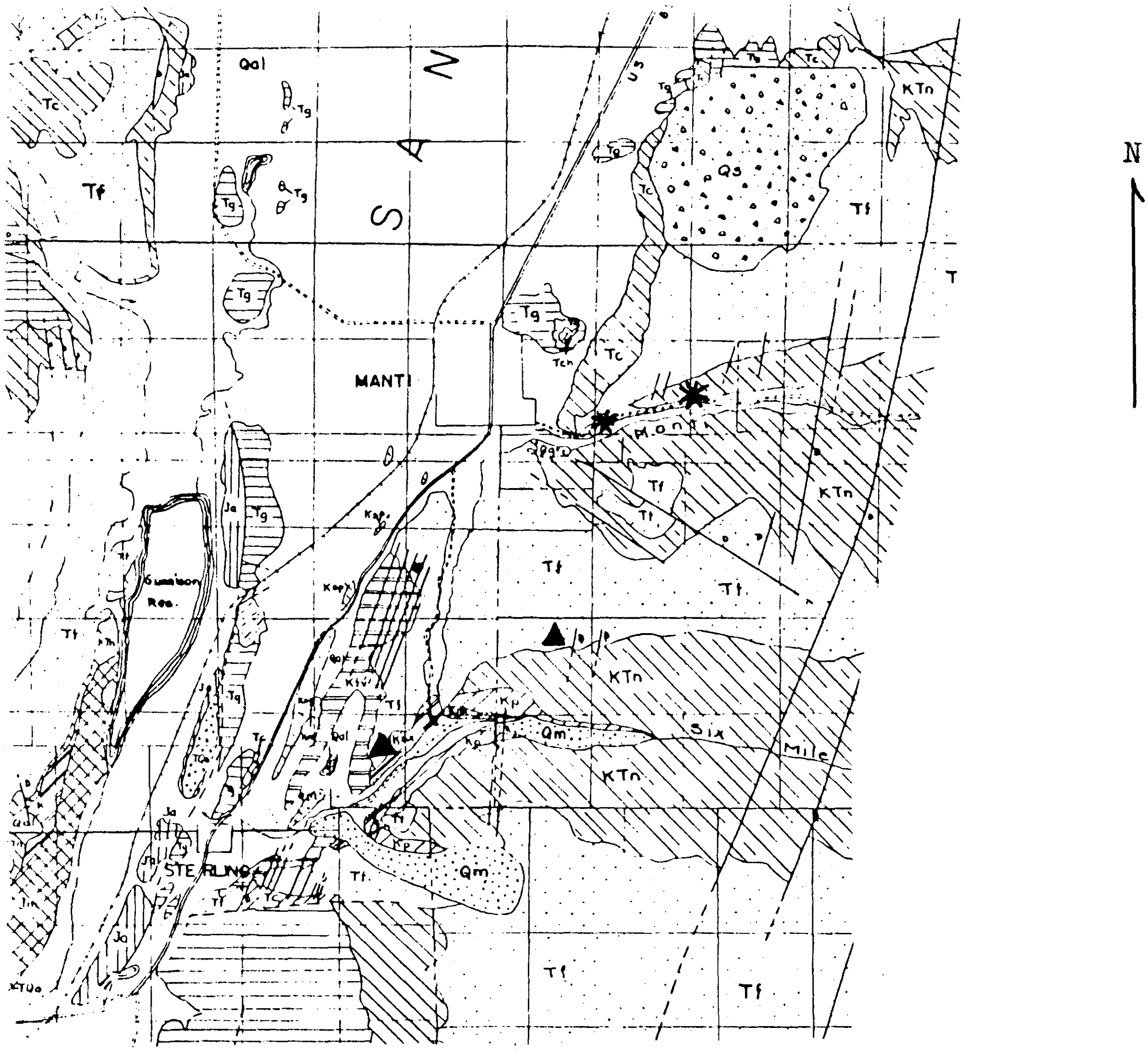
The samples were collected in July,1981 from two separate areas in Manti Canyon, Central Utah (see Map 1). A Lower Manti Canyon section was measured from which 17 samples were collected; a Middle Manti Canyon section was measured and 14 samples were obtained.

The Paleocene-Eocene Flagstaff limestone is composed of three members, the Upper, Middle, and Lower. The Upper and Lower Members are freshwater, lacustrine limestones containing freshwater gastropods. The Middle Member is a dolomitic, playa-lake limestone. Stanley and Collinson (1979) named these three members, the lowest being the Ferron Mountain Member, the middle being the Cove Mountain Member, and the upper being the Musinia Peak Member.

In previous work performed on the Flagstaff limestone by Lon McCullough (1977) an explanation for the dolomitic limestone is given. He concluded that the dolomite in the Flagstaff limestone was formed adjacent to Lake Flagstaff by evaporative pumping of groundwater. The dolomite was subsequently carried by sheet flooding into the central saline lake. This accounts for the intraclastic configuration of the dolomitic limestone within the formation. He also suggested that during X-ray diffraction, the dolomite peaks are shifted to low 2θ values from $30.99^\circ 2\theta$ to about $30.84^\circ 2\theta$ if iron is present in the dolomite of the freshwater limestone. In the Middle Member which is totally dolomitic, he had no 2θ shift for iron. Therefore, he stated that the iron rich dolomite is present only in the freshwater facies of the formation.

During my X-ray diffraction work in the two Manti Canyon sections, it was revealed that the dolomite peaks in both the freshwater and saline facies showed a downward 2θ shift. The minimum value found was $30.68^{\circ} 2\theta$. This suggests that iron is present throughout the Manti Canyon sections. Quartz is another mineral found in small amounts throughout the formation but was not a subject of study for this thesis.

Albert Dantzer (1977) carried out an X-ray diffraction study on the Flagstaff limestone. His work was on samples taken from sections in Six-Mile Canyon, Central Utah, a few miles south of Manti Canyon. Figures 1 and 2 show the relationship between the two canyons in terms of fossil evidence and calcite to dolomite ratios. Map 1 also points out the locations of the sections measured by Dantzer in Six-Mile Canyon.



1 inch = 2 miles

Compiled by C.H.Summerson

* = Manti Canyon Sections

▲ = Six-Mile Canyon Sections

GENERAL STRATIGRAPHY

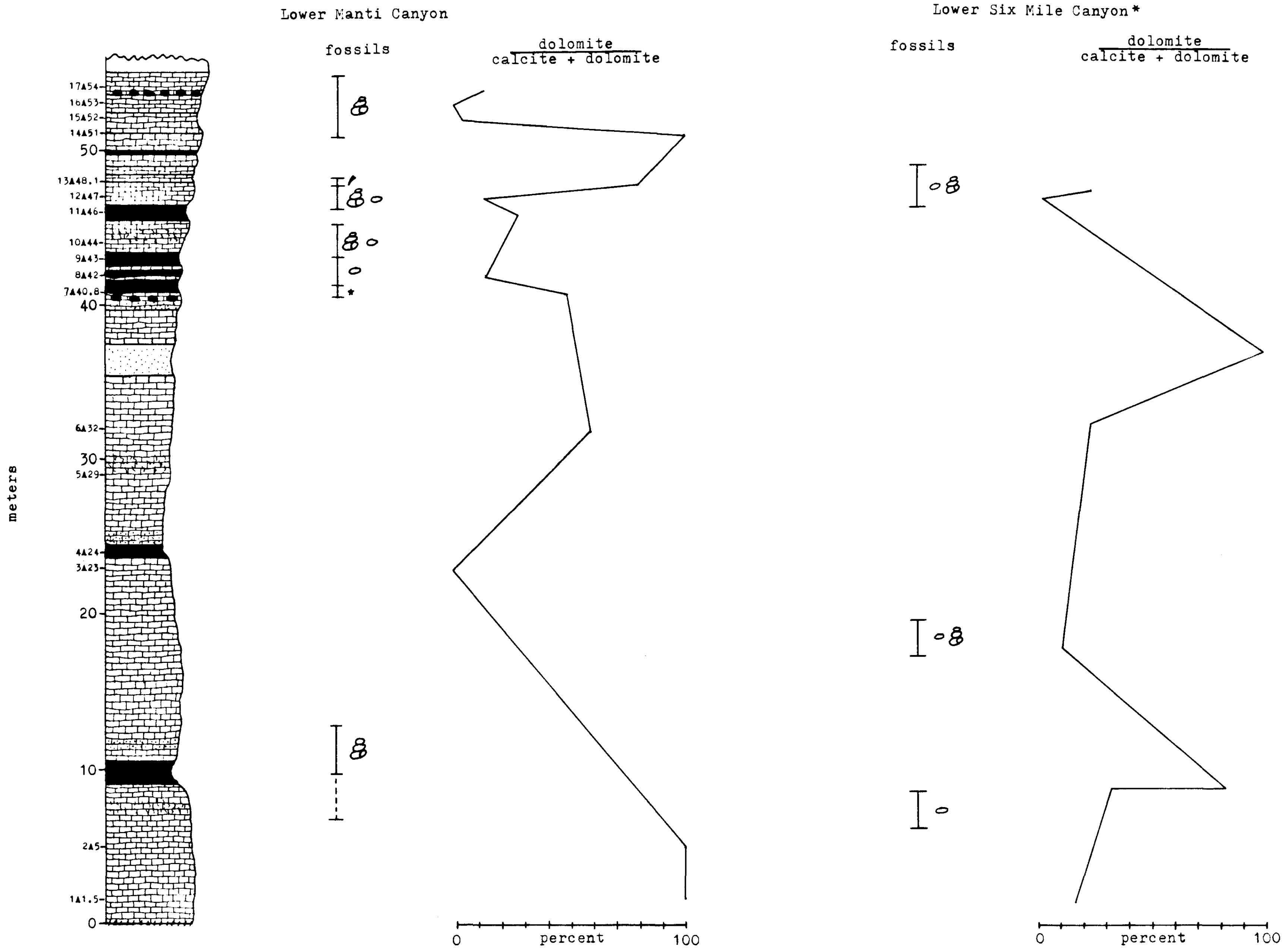
The Flagstaff Formation is underlain by the North Horn Formation and beneath that, the Price River Formation. The Colton and the Green River Formations overlie the Flagstaff Formation.

During the early Tertiary many uplifts occurred in eastern Utah. This caused a reversal of many drainage systems and subsequently a chain of lakes formed trending SW-NE through central Utah and Wyoming. Lake Flagstaff was a product of the drainage reversal. The lake was bound on the east by the San Rafael Swell and on the west by the Sevier orogenic belt (Hunt,1956). The Wasatch Plateau represents the central depositional area of the lake.

Throughout the Paleocene and Early Eocene, the lake was contracting and expanding. Previous work on the Flagstaff limestone divides the formation into three members, the Upper and Lower being the freshwater facies and the Middle Member representing the contracted, saline lake deposits.

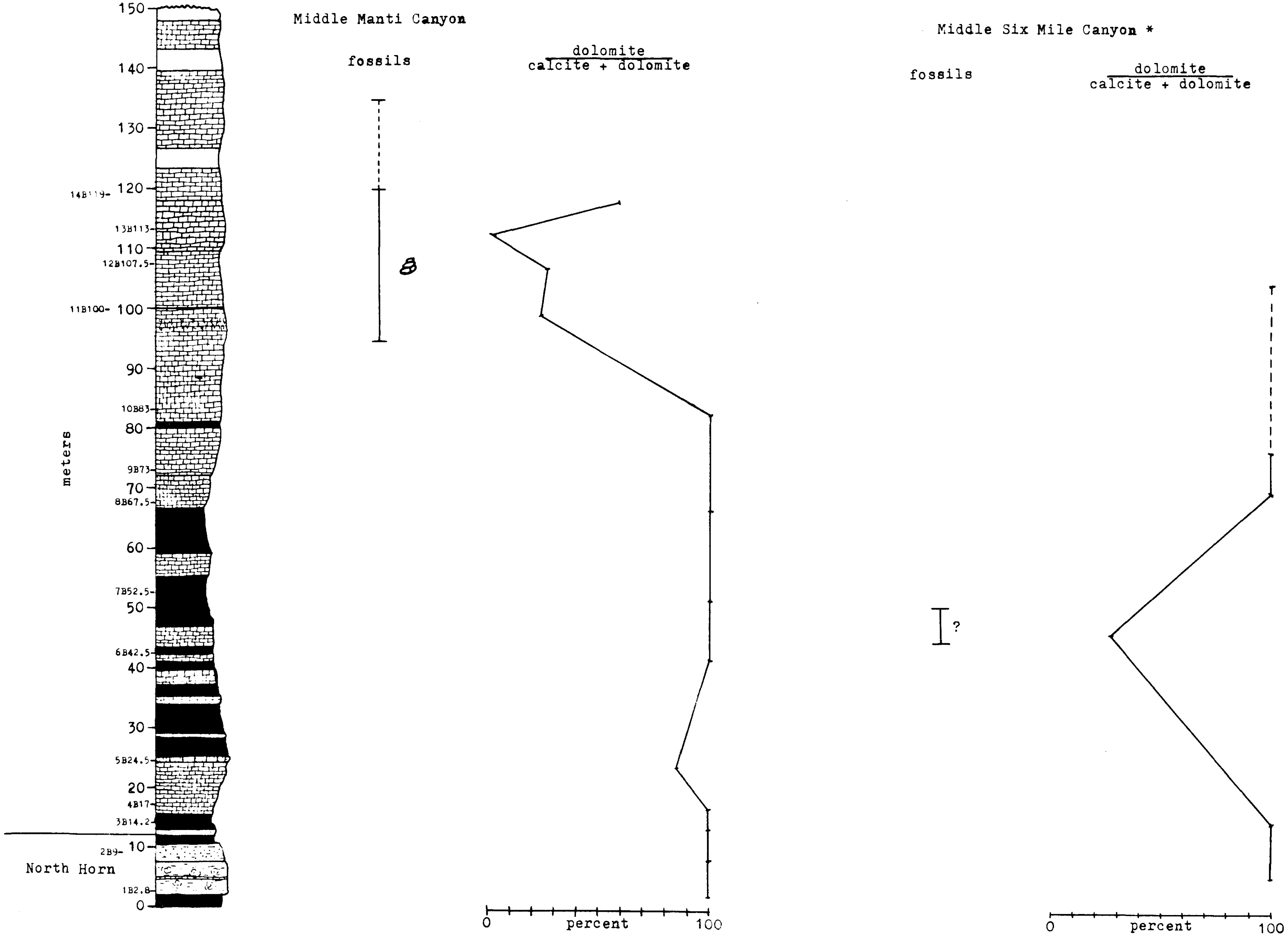
Through my X-ray diffraction work on the Flagstaff limestone in Lower Manti Canyon and Six-Mile Canyon by Albert Dantzer (1977), minor expansions and contractions are evident through the intertonguing of calcite and dolomite facies (Figure 1). In comparing the middle sections of both canyons (Figure 2), little evidence of expansion and contraction of Lake Flagstaff is present. Sandstone in the sections may be the product of drainages produced when the lake contracted.

Figure 1



* Dantzer 1977

Figure 2



* Dantzer 1977

LABORATORY METHODS

Extensive work was conducted on sample 8A42 to determine which sample preparation gave the most precise X-ray results. The precision was based on reproducibility of peak heights.

A powder consisting of minus 1 micron particles was obtained using an average of Stoke's and Wadell's Laws of settling velocities. They are the same basic equations although Wadell takes into consideration the shape of the particles. By averaging the two equations, the following expression is derived.

$$t = (23 n h) / ((s_p - s_l) g d^2)$$

t = settling time (sec)

s_l = specific gravity of the liquid (water=1g/cm^2)

s_p = specific gravity of particles (2.78g/cm^2)

h = height of settling column (5cm)

g = gravitational constant (980cm/sec^2)

n = viscosity of liquid (0.01poise)

d = diameter of particles (1micron=1x10^{-4}cm)

For a specific gravity of the particles in my study, an average between the specific gravities of calcite and dolomite was used. This resulted in a settling time of 17 hours and 20 minutes for minus 1 micron particles.

Two gram subsamples were mechanically ground in acetone for 45 minutes. The acetone was evaporated under a ventilation hood with a hot plate and the sample was collected from the dish. This procedure was repeated until 10 grams of mechanically ground sample was obtained. The sample was placed in 550 ml of distilled water for sizing. The powdered limestone immediately flocculated.

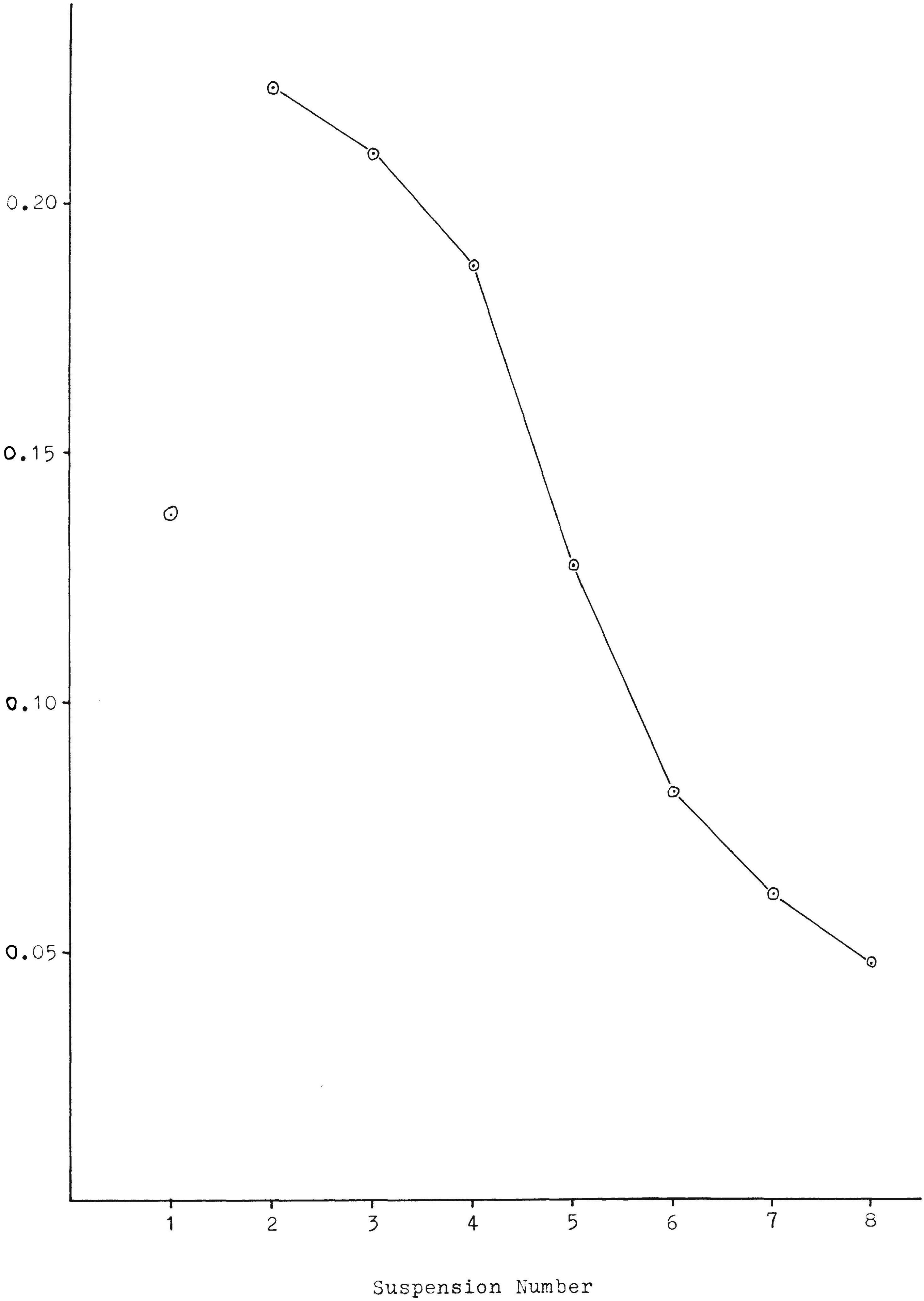
An experiment was carried out on an additional 2 grams of sample, which was prepared the same as the 10 grams of flocculated sample. The 2 grams were suspended in 120 ml of distilled water; flocculation also occurred. Then a 10% Calgon detergent and water solution was prepared and added to the sample one milliliter at a time until 5 ml total had been added to the 120 ml of water. The sample deflocculated, therefore, 5 ml of a 10% Calgon solution was employed for every 2 g of sample. Twenty five ml of Calgon solution was added to the 10 g of flocculated sample along with the beaker full of sample and solution used in the experiment. The total was now 12 g of suspended material.

The 12 g were filtered with excess water through filter candles to remove excess detergent. After heating at 75°C to remove the water, the sample was reweighed and yielded 10.4 grams.

The 10.4 g of sample was resuspended in 550 ml of distilled water. After 17 hours and 20 minutes, the top 5 cm of water was siphoned off and dried. The powder was collected and weighed. The remaining sample was resuspended. This procedure was repeated an additional 7 times until the yield was negligible. Graph 1 shows the relationship between the number of resuspensions and the yield in grams. From the 8 settlings, 1.077 g were collected of minus 1 micron particles.

An oven was used to evaporate the water from the particles. A drying oven was used on the first suspension. The evaporation rate was slower than the settling rate, therefore the suspended material had time to settle on the sides of the evaporation dish. This made it harder to recover the grains from the dish and thus, the yield fell below the curve on Graph 1. On the remaining 7 resuspensions, a mechanical convection oven with forced air was used. This made the rate of evaporation faster than the settling rate. The particles, therefore, were condensed on the bottom of the dish and more easily removed.

Graph 1



A hand-ground sample was also prepared. Two grams of sample 8A42 were ground by hand in a mortar and pestle until the powder passed through a 53 micron sieve.

Besides having two different sizes of powder to compare for variation in X-ray patterns, two slabs were also cut from sample 8A42 at right angles to each other. The slabs were X-rayed, then polished for a minute with wet 400 grit powder and an additional minute with a diamond grinder, and X-rayed again.

SPECIMEN MOUNTING TECHNIQUES

Both sizes of powder were mounted several ways and X-rayed. One mount used was the top-load, where the powder was placed in the top of the slide, flattened with a glass slide and X-rayed.

Another mount used was the back-load. This technique is demonstrated in the book by Klug and Alexander (1954). This mount has the powder loaded in the bottom of the slide. The slide is flipped over and the top is X-rayed.

The third and final mount employed was the side-load. In this mount, the powder is loaded from the side of the slide. Both the back-load and side-load are used to attempt to give the grains a more random orientation. The top-load mount may cause the cleavage faces of the grains to align with the glass used to press the powder into the slide.

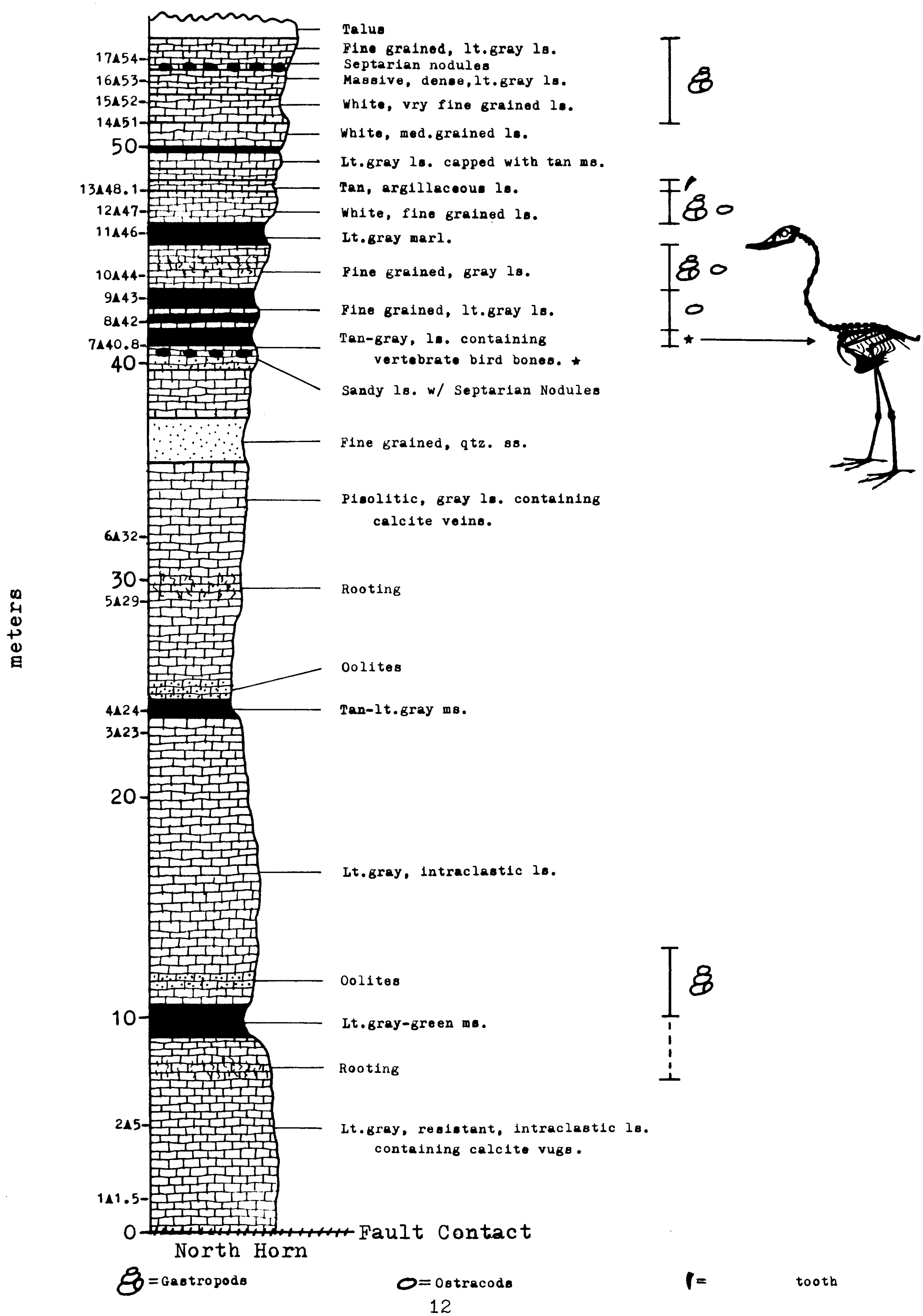
X-RAY ANALYSIS

The samples were X-rayed using a slow scan speed of $\frac{1}{2}^{\circ}2\theta$/min and run between the angles of 28 and 32 degrees. This region covered the most intense calcite and dolomite peaks. The samples were run at 25 Kv and 10 mA.

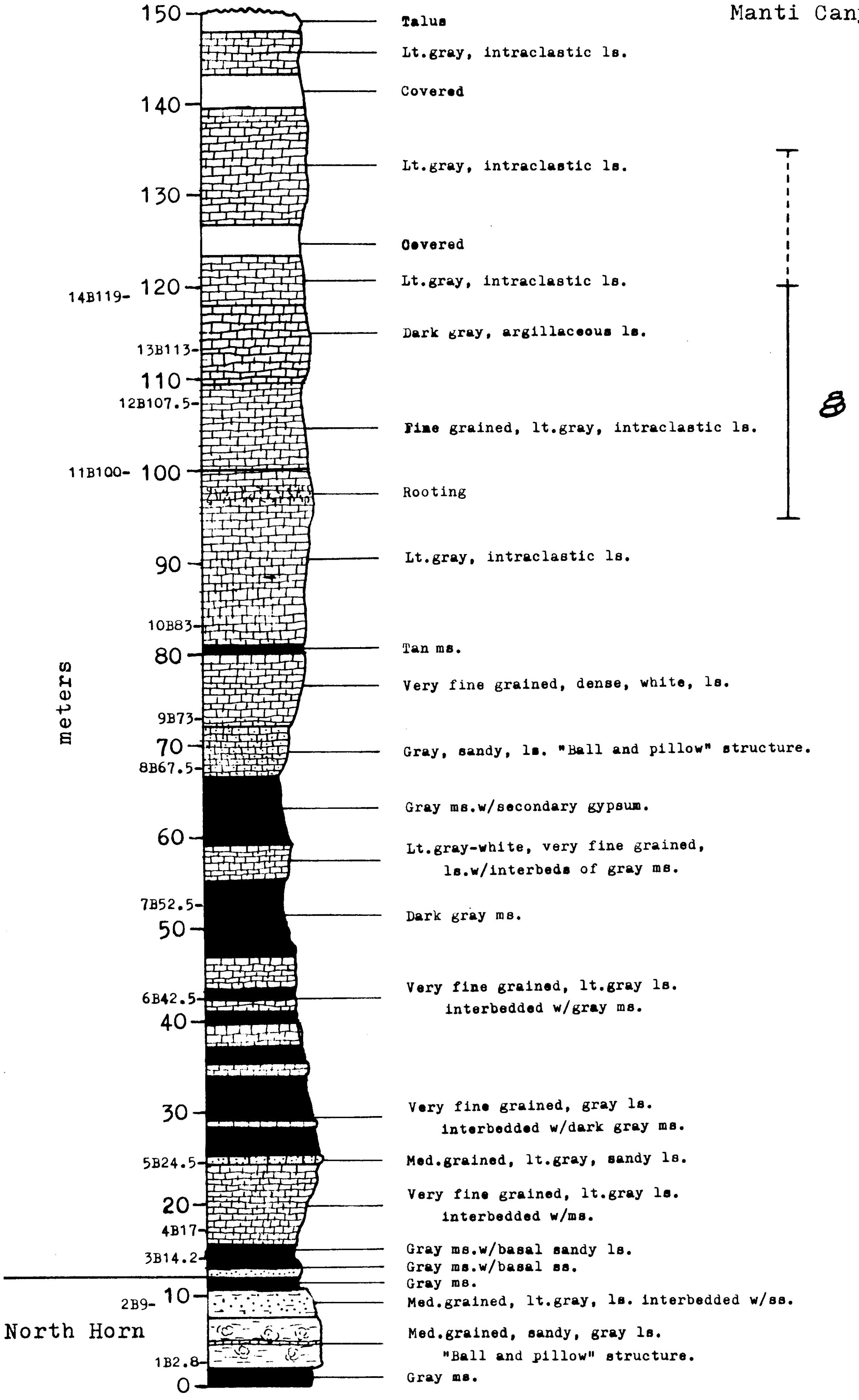
A base line was drawn on the X-ray patterns and the peak heights of the two minerals were measured. The peak height of the dolomite was divided by the sum of the dolomite and calcite peak heights to obtain a number which represents a "semi-quantitative" measure of the amount of dolomite in each sample as shown in the following equation:

$$\% \text{ Dolomite} = \frac{\text{Height of Dolomite Peak}}{\text{Height of Calcite Peak} + \text{Height of Dolomite Peak}} \times 100$$

Manti Canyon Section 1



Manti Canyon Section 2



RESULTS

Sample 8A42 was mounted and X-rayed several different ways including cut slabs. The patterns that showed the least variations were from the samples prepared by simply cutting slabs from the rock. Therefore, cut slabs were used for X-ray diffraction work from the remaining 26 samples (Appendix 3).

Each of the 27 samples was X-rayed twice (once on each side) in order to assess the reproducibility of the percentage of dolomite within each sample. Both percentages of dolomite for each sample are shown in Appendix 1 for samples collected in Lower Manti Canyon and Appendix 2 for the samples collected in Middle Manti Canyon.

The powdered limestone used for X-ray experimentation was photographed using a Scanning Electron Microscope to confirm the particle sizes. Plate 1 shows the hand-ground powder which passed through a 53 micron sieve. In the picture, the largest dimension of the particles is about 53 microns.

The minus one micron sized particles obtained through the use of Stoke's and Wadell's Laws are pictured in Plate 2. Nearly all the particles photographed are less than one micron. One problem arose with the powder during drying that is visible in Plate 3. During drying, the minus one micron particles collected on the sides of the dish and formed flakes. This may be the reason these particles gave the most variable X-ray results.

The percentage of dolomite is shown in Appendix 1 for the samples collected in Lower Manti Canyon. The percentage of dolomite for the samples collected in Middle Manti Canyon, as determined by X-ray diffraction work, is shown in Appendix 2.

CONCLUSIONS

The X-ray study on the two Manti Canyon sections show that two of the three members of the Flagstaff limestone are present. The Lower Manti Canyon section represents the freshwater, Musinia Peak Member as named by Stanley and Collinson (1979). But in Manti Canyon, as well as Six-Mile Canyon (Dantzer,1977) the limestone shows several intertongues between calcite and dolomite. This is due to the fact that the limestone in the lower canyons was deposited near the western edge of Lake Flagstaff along the Sevier-Sanpete anticline. With the deposition close to the shore of the lake, minor changes in the lake size would be more easily recorded in the rocks (as variations in calcite to dolomite ratios) than in rocks deposited toward the center of the lake.

The bottom 90 meters of the Middle Manti Canyon section represents the middle, dolomitic, Cove Mt. Member as proposed by Stanley and Collinson (1979). The upper 60 meters of the Middle Manti Canyon section makes up the Upper or Musinia Peak Member.

The variations between the calcite and dolomite facies of the Flagstaff limestone were made visible through X-ray work. This work is also substantiated by the fossil record. Figures 1 and 2 show where gaps in the fossil record coincide with the dolomitic facies of the limestone.

REFERENCES

--Cullity, B.D.,1956, Elements of X-ray Diffraction, Addison-Wesley Publishing Co.,514p.

--Dantzer, A.J.,1977, The Paleocene-Eocene Flagstaff Formation in the Six-Mile Canyon Area of the Wasatch Plateau, Central Utah: Senior Thesis, Ohio State Univ., 20p.

--Hunt, C.B.,1956, Cenozoic Geology of the Colorado Plateau, U.S.G.S. Prof. Paper, 279p.

--Klug, H. and Alexander, L.E.,1954, X-ray Diffraction Procedures, John Wiley, New York. p301-302.

--McCullough, L.A.,1977, Playa-lake and Clastic Deposition in the Paleocene-Eocene Flagstaff Limestone, Wasatch Plateau, Utah: Master's Thesis, Ohio State Univ., 116p.

--Spieker, E.M.,1949, Guidebook to the Geology of Utah, no.4, Utah Geological Society, 106p.

--Stanley, K.O. and Collinson, J.W.,1979, Depositional History of Paleocene-Lower Eocene Flagstaff Limestone and Coeval Rocks, Central Utah: A.A.P.G.Bull., 63:311-323.

--Tettenhorst, R.,1982, Personal Communication.

--Wells, N.A.,1977, Paleocene-Eocene Lake Flagstaff of Central Utah: Master's Thesis, Ohio State Univ., 174p.

--Zawiskie, J.,1982, Personal Communication.

Appendix 1. Stratigraphic and chemical criteria of samples from the Lower Manti Canyon section.

Sample Number	Distance above base (m)	Dol/Dol+Cal (%)
1A1.5	1.5	100
1A1.5	1.5	100
2A5.0	5.0	100
2A5.0	5.0	100
3A23.0	23.0	0
3A23.0	23.0	0
6A32.0	32.0	67
6A32.0	32.0	56
6A32.0	32.0	61
7A40.8	40.8	54
7A40.8	40.8	52
8A42.0	42.0	16
8A42.0	42.0	14
9A43.0	43.0	11
9A43.0	43.0	10
11A46.0	46.0	31
11A46.0	46.0	29
12A48.1	48.1	83
13A48.1	48.1	82
14A51.0	51.0	100
14A51.0	51.0	100
15A52.0	52.0	4
15A52.0	52.0	5
16A53.0	53.0	3
16A53.0	53.0	3
17A54.0	54.0	15
17A54.0	54.0	14

Appendix 2. Stratigraphic and chemical criteria of samples from Middle Manti Canyon section.

Sample Number	Distance above base (m)	Dol/Dol+Cal (%)
1B2.8	2.8	100
1B2.8	2.8	100
2B9.0	9.0	100
2B9.0	9.0	100
3B14.2	14.2	100
3B14.2	14.2	100
4B17.0	17.0	100
4B17.0	17.0	100
5B24.5	24.5	80
5B24.4	24.5	88
6B42.5	42.5	100
6B42.5	42.5	100
7B52.5	52.5	100
7B52.5	52.5	100
8B67.5	67.5	100
8B67.5	67.5	100
10B83.0	83.0	100
10B83.0	83.0	100
11B100.0	100.0	26
11B100.0	100.0	17
12B107.5	107.5	23
12B107.5	107.5	26
13B113.0	113.0	0
13B113.0	113.0	0
14B119.0	119.0	63
14B119.0	119.0	53

Appendix 3. Dolomite to Calcite ratios of sample 8A42 using various mounting techniques.

Type of Preparation	Fast Scan $2° 2\theta$/min*	Slow Scan $\frac{1}{2}° 2\theta$/min*
SL/P/-1	15	
SL/P/-1	14	
#TL/P/-1	16	15
#TL/P/-1	15	16
BL/P/-1		16
BL/P/-1		16
#SB1	14	13
#SB2	14	11
#SB3	17	16
#SB4	16	14
SB3POL		15
SB3POL		15
SB3POL		15
SB4POL		15
SB4POL		15
SB4POL		15
TL/P/-53	19	19
TL/P/-53	15	
TL/P/-53	16	
BL/P/-53	20	17
BL/P/-53	15	
SL/P/-53	21	17

SL = Side-load
TL = Top-load
BL = Back-load
SB = Cut Slab
POL = Polished

P = Powder
-1 = Minus 1 Micron (powder size)
-53 = Minus 53 Microns (powder size)

= fast and slow scans run on different days.

*Expressed as a percent of dolomite.

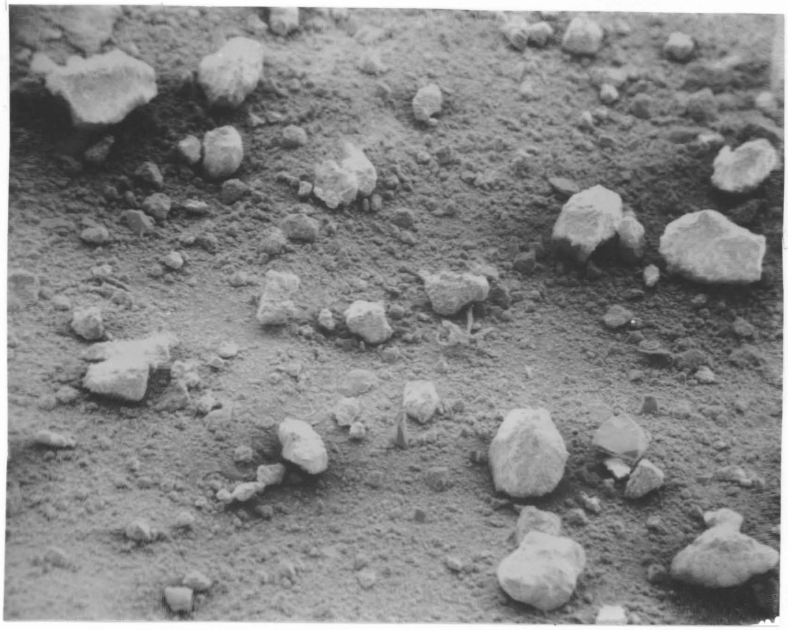


Plate 1

1cm = 50microns

200X

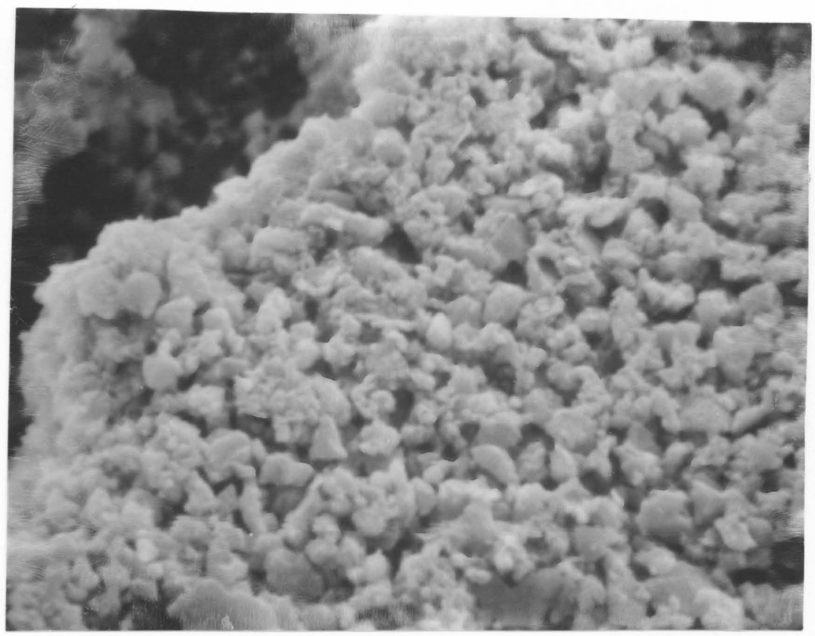


Plate 2

1cm = 2microns

5000X

Plate 3

1cm = 50microns

200X